

Research Highlight

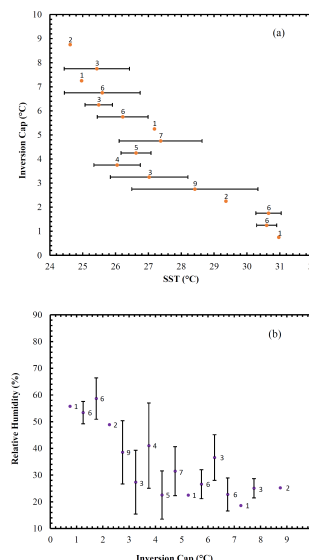
The North American monsoon (NAM) supplies about 60% to 80%, 45%, and 35% of the annual precipitation for northwestern Mexico, New Mexico, and Arizona, respectively. An understanding of the major governing processes of this phenomenon is necessary to guide improvement in global and regional climate modeling of the NAM, as well as NAM's impacts on the summer circulation, precipitation, and drought over North America. In this study, we use various observations and reanalyzed data and suggest a physical mechanistic understanding for how Sea Surface Temperatures (SSTs) in the Gulf of California (GC) and the tropical eastern Pacific affect the NAM on both the local and synoptic scale, respectively.

At the local scale, analysis of satellite observations and ship rawinsondes launched over the GC during the North American Monsoon Experiment in 2004 show that the Marine Boundary Layer (MBL) inversion over the GC appears to control GC moisture transport from the surface to mid-atmospheric levels. Before onset of the NAM, when GC SSTs are cooler (i.e., relative to the SST threshold of 29.5°C), the MBL over the GC extends less than a few hundred meters above the surface and contains moist air conditioned by the sea surface. The MBL is capped by drier warmer air, leading to a shallow and strong inversion that traps moist air inside the shallow MBL and inhibits it from ascending into the free troposphere. When GC SSTs exceed 29°C (and this often coincides with the onset of more intense rainfall in Arizona), the inversion cap becomes very weak (i.e., <2.5°C) and/or disappears, allowing the trapped moist air in the MBL to mix with free tropospheric air. This corresponds with a mean relative humidity >48% in the lowest 2 km and leads to a deep moist layer that can be advected by the along-gulf flow (across-gulf flow) to enhance precipitation in Arizona (i.e., the NAM core region).

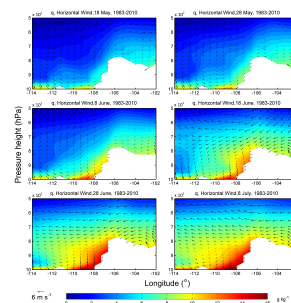
Gulf surges may also play a role in weakening or eroding this inversion because they are associated with cooling in the low-level free troposphere. Evidently, increasing GC SSTs diminish the inversion from below, while gulf surges may erode the inversion from above with both factors contributing to a weaker or absent inversion.

At the entrance to the GC, we show that rising SSTs may also erode the coastal MBL inversion. There is evidence that moisture in this region may be released to the lower free troposphere in a similar way as described for the GC. In this way, tropical surface water moving poleward along the coast may be promoting convection along the Sierra Madre Occidental (SMO) south of the GC. A field campaign in this region, including a research ship with rawinsondes and/or aircraft soundings, could investigate this hypothesis in the future.

On the synoptic scale, climatology studies based on satellite SST and reanalyzed data of outgoing longwave radiation, horizontal wind, specific humidity, and 500 hPa geopotential height from 1983 to 2010 demonstrate that there is an association between northward advection of coastal warm SSTs (>27.5 °C), northward propagation of NAM convective activity, the NAM anticyclone, and NAM-induced strong subsidence in the eastern Pacific. From mid-May to mid-July, tropical surface water advances northward along the west coast of Mexico into the GC, whereas NAM convection during the same period progresses northward along the western slopes of the SMO. Therefore, we suggest that the coastal advection of tropical surface water might be responsible for the poleward advancement of deep convection and precipitation along the SMO. The NAM anticyclone can form as a result of atmospheric heating in the region of NAM deep convection. Thus, the poleward propagation of NAM convection may result in poleward migration of the NAM anticyclone, and poleward movement of the anticyclone center appropriates mid-level moisture for convection further north along the SMO, complementing any low-level moisture from the Pacific coastal region. More research is necessary to investigate



a) Dependence of inversion cap on mean SSTs and b) dependence of low-level relative humidities on inversion cap based on mean low-level relative humidity for all rawinsondes onboard the research ship in the GC north of 24.1°N during June and August 2004; bars are indicative of standard deviations and the numbers on data points represent the frequency of data in their bins. Data points with no standard deviation are based on less than three rawinsondes.



Time evolution of a zonal vertical cross-section of the 1983 to 2010 specific humidity (shaded) and horizontal wind vector climatology at 25°N latitude from May 18 to July 8 every 10 days; specific humidity shading interval is 0.5 g/kg.

this hypothesis and to identify the processes responsible for the NAM rainfall, which accounts for most of Northern Mexico's water supply.

Strong subsidence occurs further northwest of the NAM convective system and moves northward from the Baja California peninsula in mid-May to southern California in mid-July, promoting drier conditions in these regions. This strong subsidence is generated as a result of Rossby wave response to the west of the NAM with mid-latitude westerly winds.

The next step might be investigating the local-scale mechanism using a regional model (i.e., Weather Research and Forecasting) and evaluating the effects of various prescribed GC SSTs on the inversion and moisture over the GC, as well as the precipitation in the NAM region. The enhanced observational network field campaigns may provide valuable measurements for evaluating the model results and improving the simulations in the NAM region.

Reference(s)

Erfani E and DL Mitchell. 2014. "A partial mechanistic understanding of the North American monsoon." *Journal of Geophysical Research – Atmospheres*, 119(23), 10.1002/2014JD022038.

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Cloud-Aerosol-Precipitation Interactions